Game Sound Technology and Player Interaction:
Concepts and Developments

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Chapter 2
Sound for Fantasy and Freedom

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ABSTRACT

Sound is an integral part of our everyday lives. Sound tells us about physical events in the environment, and we use our voices to share ideas and emotions through sound. When navigating the world on a day-to-day basis, most of us use a balanced mix of stimuli from our eyes, ears and other senses to get along. We do this totally naturally and without effort. In the design of computer game experiences, traditionally, most attention has been given to vision rather than the balanced mix of stimuli from our eyes, ears and other senses most of us use to navigate the world on a day to day basis. The risk is that this emphasis neglects types of interaction with the game needed to create an immersive experience. This chapter summarizes the relationship between sound properties, GameFlow and immersive experience and discusses two projects in which Interactive Institute, Sonic Studio has balanced perceptual stimuli and game mechanics to inspire and create new game concepts that liberate users and their imagination.

INTRODUCTION

At the Interactive Institute, Sonic Studio in Piteå, Sweden, we do research on sound and auditory perception in order to find new ways to use sound, new contexts where sound can be utilized, and new applications for sound in general. Of special interest to us is how sound resembles and differs from other sensory stimuli and how this can be put to play. In our work we use perspectives and methods from art, science, and technology and we utilize digital technology as a vehicle for our ideas and experiments.

In a series of projects we have explored intuitive, emotional, imaginative, and liberating properties of sound. These projects have resulted in new insights and knowledge as well as in new and innovative applications for sound, audio, and technology. In this chapter I will describe our perspective on a number of sound properties and how

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we have put these to work in various ways. The projects are based on and inspired by an ecologic and everyday-listening approach to sound, like the ones proposed by R. Murray Shafer, William Gaver, and their followers.

As human beings, we are good at interpreting the soundscape constantly surrounding us. When we hear a sound we can make relatively accurate judgments about the objects involved in generating the sound, their weight, the materials they are made of, the type of event or series of events that caused the sound, the distance and direction to the sound source, and the environment surrounding the sound source and the listener, for example. Much of the existing research on sound and auditory perception is about how to convey clear and unambiguous information through sound. In computer games, however, the aim is also to create other effects, effects that have as much to do with emotions, the subconscious, intuition, and immersion as they do with clear and unambiguous messages.

This article describes a couple of projects in which we have worked with the balance between eye and ear, between ambiguity and un-ambiguity, between cognition and intuition and between body and mind. The aim has been to create experiences built on a multitude of human abilities and affordances, mediated by new media technology.

In a traditional computer game setting, the TV screen or computer monitor is the center of attention. The screen depicts the virtual game world and the player uses some kind of input device, such as a game pad, a mouse, a keyboard, or a Wiimote, to remotely control the virtual gameworld and objects and creatures in it. The action takes place in the virtual world and the player is naturally detached from the game action by the gap between the player's physical world and the virtual world of the game. Much work has to be done and complex technology used in order to bridge that gap and to have the player experience a sense of presence in the virtual gameworld. The aim is to make the player feel as immersed as possible in the game experience and to make her suspend her natural disbelief. To achieve this, the computer game industry must build broader and broader bridges over the reality gap to make the virtual game reality more immersive. The traditional way to increase immersion and suspension of disbelief has primarily been to increase graphics capability and, today we can enjoy near photo-realistic, 3D-graphics in real time. But there might be alternative ways to tackle the problem. Potentially, computer games could be more engaging and immersive without having to build long and broad bridges over the reality gap. What about narrowing the gap instead of building broader bridges over it?

BACKGROUND

Sound and light work in different ways and reach us on complementary channels. Our corresponding input devices, the visual and auditory perceptions, show both similarities and differences and we have an innate ability to experience the world around us by combining the visual, auditory, touch and olfactory perceptions into one, multimodal whole. We are built for and used to handling the world through a balanced mix of perceptual input from many senses simultaneously. This can be exemplified in different ways. One is by crossmodal illusions, for example, the McGurk effect (Avanzini, 2008, p. 366) which shows how our auditory perception is influenced by what we see. Another example is the ventriloquist illusion in which the perceived location of a sound shifts depending on what we see (O'Callaghan, 2009, section 4.3.1). If the signal on one sensory channel is weak, we more or less automatically fill in the gaps with information from other channels and, in this way, we are able to interpret the sum of sensory input and make something meaningful of that sum. Watching lip movements in order to hear what your friend is saying at a noisy party is just one everyday example of this phenomenon. A third example is Stoffregen and Bardy's concept of "global array" (Avanzini, 2008, p. 350).

According to this concept, observers are not separately sensitive to structures in the optic and acoustic flows, but are rather sensitive to patterns that extend across these flows: the global array. Another way to describe this is that we do not "see and hear" but rather "see-hear", what we perceive is the sum of sensations reaching our different modalities.

What we really hear, what a sound is, where a sound is located and so forth are questions that philosophers have been arguing over for several hundreds of years. O'Callaghan (2009) gives a broad summary of the history and current state of the field. What most philosophers and sound researchers agree on is that sounds are the result of events in the physical world. Sound holds information about these events and the objects involved in them. This means that to our perception, sounds are strongly linked to the physical world and we are "hard wired" to treat sounds as tokens of physical activity, matter in motion and matter in interaction.

In this context the pioneering work of William Gaver (1993) on sound classification and listening modes is still often cited and relevant for game sound design. Gaver makes a distinction between musical listening and everyday listening. In musical listening, you listen to the acoustic properties of the sound, for example, its pitch, loudness, and timbre. In everyday listening, on the other hand, you listen to events rather than sounds. When you hear a car passing by or you hear a bottle breaking you do not pay much attention to pitch or loudness but more to the event as such. In everyday listening, the interpretation and the mapping of sounds to the individual's previous experiences and memories are crucial. When a bottle crashes against the floor, loses its original shape and turns into a number of smaller and larger pieces, this is immediately obvious to the eye. But, in order to be able to pinpoint the event that caused the sound of the broken bottle, the ear has to learn and form a memory that connects the sound of broken glass to the event of a bottle crashing and losing its shape. Even if the individual has a previous experience and memory that connects the sound of broken glass to the event of a broken bottle, the ear, not knowing the exact cause of the sound, might hesitate. Was it a bottle that crashed or was it perhaps a large drinking glass that broke? The eye can give the correct answer, whereas the ear is left to interpret and to guess in various degrees.

Tuuri, Mustonen, and Pirhonen (2007) have continued along this path and propose a hierarchical scheme of listening modes. Two of these are preconscious, two are source-oriented, three are context-oriented and one is quality-oriented. In the two preconscious-oriented listening modes, the focus is on what reflexive, emotive and associative responses a sound evokes in the listener. In the two source-oriented modes, the focus is on how the listener perceives the source of a sound and what event caused it. In the three context-oriented modes, the focus is on whether the sound had a specific purpose, if it represents any symbolic or conventional meaning, and if the sound in that case was suitable and understandable in the context. In the last, quality-oriented listening mode, the focus is on the acoustic properties of the sound, its pitch, loudness, duration and so forth. To use these or other, complementary, identified listening modes is a powerful way to inform the sound design process of not only computer games, but sound design processes in general. The important thing to notice here is that research on listening modes in general shows that sound can indeed be used to evoke emotions and associations, to communicate properties of physical objects and events and to convey meaning and purpose.

Already from the time before we are born our auditory perception starts giving us information about the world around us (Lecanuet, 1996). From day one we start building our library of associations to individual sounds and to whole soundscapes. Gradually, we learn what they mean and we train our ability to interpret them. Furthermore, some researchers argue that we experience sounds "as of" a bigger whole. O'Callaghan (2009) argues

that the sound of hooves of a galloping horse is not identical with the galloping. Instead, it is part of the particular event of galloping: "Auditory perceptual awareness as of the whole [sic] occurs in virtue of experiencing the part" (part 2.3.2). This strong linkage between the sounds we hear and the physical world we inhabit can be brought into play in computer games through rich soundscapes in order to convey information about objects, environments, and events in the game world. Try this simple experiment. Pick an environment with a reasonable number of activities, people, birds, machines or whatever you can find that makes everyday sounds. Close your eyes and try *not* to interpret, make associations and create mental pictures from what you hear. It is very hard to put the auditory interpreter to rest and this is true for sounds from all types of sources, including the headphones playing sounds from your iPod. This interpretation, mapping, or disambiguation of individual sounds and whole soundscapes involves high-level mental processes related to our conscious and subconscious, cognitive and emotional layers. As such, these processes have the potential to invoke a myriad of physical and mental responses: fear, flight, well-being, happiness, anger, understanding and so on. In computer game design, this means huge potential to both convey cognitive meaning and to create moods and affect.

Auditory perception can be understood as becoming aware of the whole by virtue of the parts. Sounds can also be said to be more ambiguous and leave wider space for interpretation than visual stimuli do, at least when it comes to interpreting where and what we have heard. In Human Computer Iinterface (HCI) contexts, ambiguity has often been thought of in terms of disadvantage and problem (Sengers & Gaver, 2006) and much, perhaps even a majority, of the research done in the field has tried to overcome this and find ways to create clear and unambiguous systems and interfaces. Research on sound interaction design is no exception to this, as described by, for example, Gaver (1997). This is true also when it comes to sound in computer games but, in this context, the need to interpret and disambiguate the computer game system is not the only aspect of the issue. On the contrary, some authors argue that ambiguity and the need to interpret a system instead can be used as an asset (Sengers & Gaver, 2006; Sengers, Boehner, Mateas, & Gay, 2007). Here, we argue that this is certainly the case. When the ideas of ambiguity and interpretation are combined with the concepts of flow and GameFlow described below, the sum can be used to inform the game design process in new ways.

Development of computer games has so far mostly been geared towards vision. When it comes to sound in games, much of the work is inspiring case studies but less research. Sweetser and Wyeth list three aspects of usability in games that have previously been in focus for research (Sweetser & Wyeth, 2005). These are interface (controls and display), mechanics (interacting with the game-world), and gameplay (problems and challenges). Lately, also other dimensions of the design and use of computer games have started to gain interest among game researchers, dimensions that incorporate new and more complex aspects and ideas of player enjoyment and computer game design. Several research groups have, for example, made connections between interactivity in general and, more specifically, player enjoyment in games on the one hand and the concept of *flow* developed by Mihaly Csíkszentmihályi on the other. In the 1970s and 1980s Csíkszentmihályi conducted extensive research into what makes experiences enjoyable. He found that optimal experiences are the same all over the world and can be described in the same terms regardless of who is enjoying the experience. He called these optimal experiences flow. A flow experience is defined by Csíkszentmihályi (1990) as being "so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it, even when it is difficult, or dangerous" (p. 71).

Judging from the volume and type of work built on and derived from Csíkszentmihályi's flow principle, it can be argued that the concept is relevant in the context of computer games. Andrew Polaine (2005) has written about *The Flow Principle in Interactivity*. This work does not relate to computer games per se, but is closely related to the subject in that it connects flow with both "willing suspension of disbelief" (a term borrowed from narratives in theater and film) and the experience of play. The GameFlow model developed by Sweetser and Wyeth builds directly on the concept of flow and is a model for evaluating computer games from an enjoyment perspective. Another example is Kalle Jegers' (2009) "Pervasive GameFlow" model that takes Sweetser's and Wyeth's GameFlow concept to the pervasive game arena. A final example is Cowley, Charles, Black, and Hickey's (2008) USE model (User, System, Experience) that looks at games, player interaction, and flow from an information system perspective.

Built on the Flow concept, Sweetser and Wyeth's GameFlow model consists of eight elements for achieving enjoyment in games. The model can be used both when designing new games and when evaluating existing game concepts. In summary, according to Sweetser and Wyeth, games must keep the player concentrated through a high workload. At the same time, the game tasks must be sufficiently challenging and match the skill level of the player. The game tasks must have clear goals and the player must be given clear feedback on progression towards these goals. Enabling deep yet effortless involvement in the game can potentially create immersion in the game. According to Sweetser and Wyeth, experiences can be immersive if they let us concentrate on the task of the game without effort. "Effortlessly" can, in this context, be interpreted in several ways: one way to think about it is in terms of how true to real life a gaming experience is and how transparent the interaction with the game creating the experience it is. How the GameFlow model can be used in sound design for games is covered in more detail below.

A number of research projects report on sound and audio's ability to create rich, strong and immersive experiences using mobile platforms that give physical freedom to the users. These projects also support the general idea that sound and audio are well suited for use in the design of computer game experiences based on the GameFlow model. Reid, Geelhoed, Hull, Cater, and Clayton report on a public, location-based audio drama called *Riot 1831*. The evaluation of the project showed that a majority of the users had rich and immersive experiences created from the sounds of an audio-based narrative. Based on the results from this project, the authors argue that "immersion is a positive determinant for enjoyment (and vice versa)" (Reid, Geelhoed, Hull, Cater, & Clayton, 2005). It should be noted that the drama took place in a square in Bristol, UK, which gives this project similarities to pervasive and location-based games where the virtual gameworld and the physical world of the player are blended. Friberg and Gärdenfors (2004) report on a project in which three audio-based games (what the authors term *TiM* games) were developed. Based on audio communication with the users, the authors report that these games give the users spatial freedom, encourage physical activity and open up possibilities to create new types of interfaces for input to the game. Ekman et al. report on the development of a game for a mobile platform (Ekman et al., 2005). They point out that sound and audio can indeed be used to create immersion, but also that the use of sound does not automatically create immersion. Great care must be taken when designing the game sounds and the developers must also carefully select the best technology and equipment to play back the game audio to get the desired effects.

In two projects, the Interactive Institute's Sonic Studio has investigated how sound in games can be used to bring the user's own fantasy into play to create new gaming experiences (Liljedahl, Lindberg, & Berg, 2005; Liljedahl, Papworth, &

Lindberg, 2007). In both these projects the balance point between visible and audible stimuli from the game has been moved away from the visual and towards the audible. In both cases the users of the computer games are given only a minimum of visual information and are, instead, given rich and varied soundscapes. The projects have shown that the users have had rich and immersive gaming experiences and are given other types and amounts of freedom compared to more traditional computer games. These projects will be described in more detail later in this chapter.

Humankind has, in recent centuries, invested considerable energy and creativity in creating complex technology. We have a long tradition in replacing human capability with machinery. In the early days it was mostly muscle power that was mimicked, replaced, and superseded by steam, combustion, and, later, electricity. It can be argued that research into artificial intelligence is striving to do the same with human cognitive and emotional capabilities. Following this long tradition, it seems that we often neglect human capabilities, affordances, gifts, and needs when designing computer games and other systems. Much of the focus has been on creating photorealistic 3D-environments in real time and less on how the players' internal, fantasy-driven, "sound interpreter and mapper" can be put into play to create complementary, mental images. In the following I will describe how we at Interactive Institute, Sonic Studio work with finding ways to increase user satisfaction and involvement in gaming situations by using existing technology in slightly new ways. Often, this has meant moving complexity from technology to the user, decreasing the demands on technology used, and increasing the demands on the user to invest and spend energy physically and mentally in a game experience.

MIND THE GAP—SOUND FOR FEEDBACK AND IMMERSION

Pictures are not the real world; they are merely the shadows of it. René Magritte's provoking pipe is a painting about exactly this: the picture of a pipe and beneath it the text "*Ceci n'est pas une pipe*" (*This is not a pipe*). We are surrounded by still and moving images and we are used to treating pictures as pictures and not the real, physical world. Even the most violent computer games and Hollywood film productions are assumed to be physically and mentally non-hazardous to us just because we are supposed to be able to discriminate between reality and the fictive picture of it. Sound, on the other hand, seems to work slightly differently. When striving for engagement, immersion, and suspension of disbelief in computer games and films, sound, plays a very prominent role and, according to Parker and Heerema (2007), "sound is a key aspect of a modern video game". Natural sounds in the physical world are the result of events in that world and we become aware of physical events to a large degree through sound. It can thus be argued that sound is a strong link to the physical world. In fact, Gilkey and Weisenberger argue that "…an inadequate, incomplete or nonexistent representation of the auditory background in a VE [Virtual Environment] may compromise the sense of presence experienced by users" (quoted in Larsson, Västfjäll, & Kleiner, 2002). It is this mechanism that is utilized when creating the sound tracks to films and games. Just seeing Donald Duck smash into a wall is not enough. It is not until the sound effect is added that the nature and the full consequence of the smash are made evident to the audience. When we hear the sound of the smash, all of us have our own, slightly unique, experiences of and relationship to the sound. The sound has the power to immediately trigger our interpretation machinery and evoke memories and fantasies. In a fraction of a second the sound makes us re-live our own experiences and we can feel what Donald feels:

pain, anger, and humiliation. In this way it can be argued that the sound is playing us. Like a guitarist plucking a string that generates sound, sound is plucking our interpretation, spawning memories, understanding, and emotions. The string cannot stop the guitarist from plucking it and we cannot stop sound from triggering our understanding, our memories, associations, and emotions.

For a computer game to be successful it is crucial that the players can immerse themselves in the gaming experience and that they are invited to a gameworld and game experience in which they are willing to suspend their natural disbelief. After all, *World of Warcraft* is not the real world. In their GameFlow concept, Sweetser and Wyeth (2005) set up a number of criteria that game designers and game researchers can use when designing and evaluating games with respect to immersion and suspension of disbelief. Some of these criteria are general, overarching principles that relate to many human activities, while other criteria relate more closely to gaming and the media used to convey the game's metaphor and narrative. The GameFlow model lists the following criteria for player enjoyment in games:

- **Concentration**. Games should require concentration and the player should be able to concentrate on the game
- **Challenge**. Games should be sufficiently challenging and match the player's skill level
- **Player Skills**. Games must support player skill development and mastery
- **Control.** Players should feel a sense of control over their actions in the game
- **Clear Goals.** Games should provide the player with clear goals at appropriate times
- **Feedback**. Players must receive appropriate feedback at appropriate times
- **Immersion**. Players should experience deep but effortless involvement in the game
- **Social Interaction**. Games should support and create opportunities for social interaction (Sweetser & Wyeth, 2005).

As can be seen from the list, these criteria are very general and could be applied to many aspects of life, from children's play to high school education, working life, and leisure. When it comes to sound design for computer games, some of these criteria are more relevant than others. When looking at Tuuri, Mustonen, and Pirhonen's (2007) hierarchical listening modes, a clear link to the GameFlow concepts Feedback and Immersion criteria can be found. Sweetser and Wyeth divide the Feedback criterion into the following parts:

- Players should receive feedback on their progress towards their goals
- Players should receive immediate feedback on their actions
- Players should always know their status or score (Sweetser & Wyeth, 2005).

The Immersion criterion is similarly divided into the following parts:

- Players should be less aware of their surroundings
- Players should be less self-aware and less worried about everyday life or self
- Players should experience an altered sense of time
- Players should feel emotionally involved in the game
- Players should feel viscerally involved in the game (Sweetser & Wyeth, 2005).

Given our ability to listen on several cognitive abstraction levels, as indicated by Tuuri, Mustonen, and Pirhonen's hierarchical listening modes, it can be argued that sound is well suited to communicate feedback to the user and to substantially add to the game's ability to immerse the player in the gaming experience. In the following

we will look at how sound can be used and what sound properties could be brought into play in order to give immediate and continuous feedback to users, to help them become less aware of their surroundings and themselves, and to help them get involved in the game.

SOUND PROPERTIES AT YOUR DISPOSAL

There are a number of properties of sound as a physical, acoustic phenomenon that, in conjunction with the inherent workings of our auditory perception and our ability to use different listening modes, are at our disposal to use, explore, and exploit when designing computer game experiences. Most of these properties are well known in everyday contexts and most people will immediately be able to connect to the descriptions of them, have own experiences of them and to understand the implications of them. These properties can, of course, be described in physical and acoustic terms of frequency, amplitude, overtone spectrum, envelopes and so forth. Unfortunately these terms say very little about our human experiences of sounds, sound sources, and soundscapes. It is therefore important to also describe sound properties in relation to how our hearing works. The following is a summary of what we have discussed above and an attempt to start making the discussion more concrete and applicable to sound design for computer games.

Omni-Directionality

Sound is omni-directional and reaches our ears from all directions (almost) simultaneously. Actively and consciously, as well as automatically and pre-consciously, we use this omni-directionality to navigate in our everyday lives. Even though we do not have to look out for saber-toothed tigers anymore, we are constantly warned for cars and buses from left and right, falling trees from behind, and other dangers. Our ears are under a constant bombardment of auditory input from all directions and we cannot simply turn away from a sound. To be able to handle all this information and to avoid fatigue and sensory overload, we handle most of the input subconsciously.

Luckily, we also have the ability to focus on specific parts in the soundscape. We can, for example, isolate a conversation with a friend in a noisy restaurant from a dozen nearby, unrelated conversations. This is often referred to as "the cocktail party problem" (Bregman, 1990, p. 529).

In GameFlow terms, the omni-directional qualities of sound relate to both feedback and immersion. Sound for feedback from a game does not force the user to look at a special location on a screen: in fact, it does not require a screen at all. Sound is a strong carrier of emotions, events, and objects, as discussed above. In our everyday lives, we are also used to being surrounded by sound. Mimicking this in a computer game scenario can make profound contributions to the immersive qualities of the game.

Uninterruptible

Along the same line is the fact that we do not have "earlids" and cannot just shut our ears to get rid of the sounds around us or choose to hear just one of the sounds of the total mass that reaches our ears. From an evolutionary point of view, it has been an advantage to get early warnings and hear all dangers, not only the dangers you choose to listen to, but all. It also means that our eyes and our ears are designed differently and that the streams of sensory input from those senses complement and interact with each other. Again, this means that a constant stream of input data must be handled. The way to cope with this is to do it subconsciously.

In our everyday lives we are submerged in the ever-present stream of sounds from the world surrounding us. By supplying a relevant and well-designed stream of sounds from a computer game, the users can get constant and natural feedback

on their actions, very much like in real life. This in turn adds in a natural way to the sought-after effortless immersion.

Sound Connects to the Physical World

Sound connects you to the physical world by telling about physical objects and events that involve physical objects. We can be described as hardwired to perceive and automatically interpret sounds as results of events occurring in the physical world. This is true even if the sound is mediated through a loudspeaker: our internal interpreter does not make much difference between sounds from a physical coffee cup being placed on a table and the recorded sound of the same event played back through a pair of headphones as long as the technical quality is sufficient. It is still a coffee cup being placed on a table. As with the real-world example you were asked to listen to above, try listening to a film with your eyes shut. It is virtually impossible to turn off the flow of images, feelings and associations flowing through you as you listen. You have to concentrate very hard on something else not to be affected by the sounds that reach your ears. The sound of a dentist's drill gives a direct bodily sensation and you can almost feel the drill in your own mouth. The picture of the drill alone, without the sound, does not have the same power over our imagination, emotions, and physiology.

Again, sound can be used to immerse the user in the gameworld in a way that strongly resembles the way we handle and work in everyday life.

Sound Can be Ambiguous

We constantly hear sounds from all directions and, to some degree, we can decide the direction and the distance to the sound source. At will, we can consciously filter out discrete sounds of special interest to us from the whole soundscape around us, but we are also forced to process most of what we hear subconsciously.

Often, we do not know exactly what the source of a sound is or from what direction and distance it comes. We can hear a vehicle approaching from behind but have to guess what type of vehicle it is and how fast it is approaching. We can roughly tell if it is a truck or a car and make educated guesses about when it will pass us, but usually not more than that. Sound leaves a relatively large space within which we can (or are forced to) fill out the details ourselves and make assumptions and interpretations based on our individual memories, experiences and associations.

When telling stories, making films or designing computer games, this ambiguity can be of great value. By planting a well-designed sound at the right moment, you can trigger a person's imaginative and emotive mechanisms by forcing her to consciously or subconsciously interpret and disambiguate the sound. Leaving the user space open to her own interpretation, inviting her and giving her the freedom to use her own imagination can potentially help the user to be emotionally and viscerally involved in the game.

Sound Reaches us on Subconscious Channels

Our ears are constantly capturing the soundscape around us. If all that data were to be processed by the cognitive and conscious layers in our brains, we would either suffer from mental overload or have another brain constitution. But thanks to the limited bandwidth of our consciousness, our subconscious, emotional and intuitive layers process most of the sounds we hear.

This does not mean that we are not affected by what our ears pick up and what our brains are processing. What it does mean is that the effect is not totally controllable by us and that we are, to a large degree, victims of the sonic world. Often this is useful, sometimes it is stressful and sometimes it is fun. We are more or less forced

to interpret and react to what we hear. A sound heard spawns meaning and interpretations based on our previous experiences. In games this can be extremely useful as a way to invite the players to invest and get deeply involved in the game. This relates strongly to the GameFlow criterion "immersion" described above.

SOUND TYPES AT YOUR DISPOSAL

There are a number of ways to categorize and classify sounds. In this context it makes sense to use the three categories traditionally used for sound in films and computer games (Sonnenschein, 2001; see also Hug, 2011; Jørgensen, 2011 for more involved taxonomies of computer game sound):

- Speech and dialog. Human language brought to sound, the sounding counterpart to the visual text. The most cognitive and unambiguous of the three types often used to convey clear messages with least possible risk of misunderstanding
- Sound effects and the subcategory ambient sounds. The result of events in the physical world. A falling stone hitting the ground; air fluttering in the feathers of a bird; a mechanical clock ticking; a heavy piece of frozen wood dragged over a horizontal, dry concrete floor; the ever-present, ever-changing sounds of the atmosphere
- Music. Sometimes referred to as "the language of emotion". An integral part of human cultures since the dawn of Homo sapiens.

Note that these categories are only for clarity and discussion. It is important to point out the fact that, in reality, the possible borders between them are floating. he borders between music particularly and the other two categories have been blurred for centuries: for example, music and dialog in opera and musicals, music and ambience, and music and sound effects in games and films.

Speech and Dialog

When you want to convey a clear and unambiguous message, the human voice is a natural choice. The same is true if you want to tell a riddle or recite a poem or just want to be vague and ambiguous. Human language is so rich and there are a myriad of ways to use this in computer game contexts. Speech and dialog can be used to address several of the criteria for player enjoyment included in the GameFlow concept. They can be used to promote concentration on the game by providing a complementary source of stimuli, getting the player's attention without disrupting the player's visual focus, or spreading the total game workload on complementary channels, for instance. Sometimes it is necessary to give instructions to the player on what to do next, or what is expected from the game. If you do not want to exclude the player from an ongoing game sequence or if you have problems with limited screen size, using speech as a complement to text is one solution. Today, more and more computing and gaming platforms have built-in support for voice recognition, which means that the player can control the game by issuing voice commands. Since this is totally in line with what we do in our everyday lives, it also supports a very natural way to co-create the game world and to get a desired sense of impact upon it. Speech is a natural way to get feedback from a game on player progress and distance to game goals without having to force the player to shift visual focus to get the necessary feedback. Speech and human voices are totally natural parts of human society and of everyday lives. The human voice is therefore very well suited to making the players forget that they are participating in the game through a medium and it helps to make the game interface less visible and less obtrusive to the player. Voices can therefore be integrated into

the background soundscape of the game to give a sense of human presence.

Apart from the above-mentioned rather objective and technical uses of speech and dialog, all variations of subjective, expressive and dramatic qualities of the human voice are also available. A bad result uttered with an offensive voice will be something radically different from the same result uttered with a friendly and supportive voice. Here, the thin border between computer games, film, theater and other narrative media is clear.

Sound Effects Make it Real

Events in the physical world generate sounds. It is actually very hard to live and be active in this world without giving rise to sounds. Sounds heard in the physical world are the results of events involving physical objects. Explosions in a combustion engine, oscillations of the vocal cords in your throat, putting down your cappuccino cup on the saucer. Sounds are the proofs that you are still firmly attached to the physical world of your senses. The absence of sound, on the other hand, could be the sign that what you are experiencing is not real, that it is a dream or virtual reality.

A green rectangle silently moving over a computer screen is probably perceived as just a green rectangle on the screen. But if you add the sound of a heavy stone dragged over asphalt to this simple animation, the green rectangle automagically turns into a heavy stone. Sound and computer game audio is a bridge on which the virtual visual worlds can travel out and become part of the real, physical world.

Ambient or background sounds are the sounding counterparts to the graphic background. Having no ambient sounds is like having a pitch-black visual background and can be perceived as an almost physical pressure on the ears. Adding just a virtually inaudible ambient sound to the virtual world of a computer game can create an immediate experience of presence and reality. The silent virtual world that was locked in can be perceived as freed and part of the physical world through the added sound.

Friberg and Gärdenfors use a number of categories for the sounds in the *TiM* games mentioned above. Most of their categories can be seen as subcategories to the traditional sound effect category. The categories listed by Friberg and Gärdenfors (2004) are:

- *Avatar sounds* refer to the effects of avatar activity, such as footstep sounds, shooting or bumping into objects
- *Object sounds* indicate the presence of objects. They can be brief, recurring sounds or long, continuous sounds, depending on the chosen object presentation
- *Character sounds* are sounds generated by non-player characters
- *Ornamental sounds* are sounds that are not necessary for conveying gameplay information, such as ambient music, although they enrich the atmosphere and add to the complexity of the game.

In GameFlow terms this means that sound effects and ambient, background sounds can add to several of the criteria for player enjoyment. Presenting a lot of stimuli to the player on various channels is crucial for the ability of the player to concentrate on the game. We are also used to constantly interpreting the soundscape surrounding us, and a well designed game soundscape will have great potential to grab the player's attention and help them focus on the game. Sound effects are today absolutely necessary for feedback to the players of computer games. Everything from game control commands issued by the player to virtual events caused by non-player characters can be signaled and embodied using sounds.

Sound effects and ambient sounds are very important for player immersion and to involve the player emotionally and viscerally in the game. Many of the sound stimuli that reach our ears are processed subconsciously and handling sound

on this level of perception is totally natural to us. This fact also supports the idea that sound is very well suited to adding to the total experience of immersion in the game world.

Music Makes You Feel

Sound in general and music in particular have a very strong ability to touch our feelings. Music works emotionally in two significant ways. Firstly, it tells us stories about feelings that we do not necessarily feel ourselves: the music works like sounding pictures of emotions (Gabrielsson & Lindström, 2001, p. 230). Secondly, music can have the power to induce feelings in us, that is, to actually make us feel (Juslin & Västfjäll, 2008, p. 562). Today, the borders between music, sound effects, ambient background sounds and voices become more and more blurred and music is used as sound effects and sound effects can be used as music. It can therefore be hypothesized that the emotional qualities of music are also, to some extent, true for other types of sounds.

Research has shown that music alone, in the absence of supporting pictures or other sensory input, can in many cases and for a majority of people induce feelings of happiness and sadness. Most people can also accurately tell if a piece of music is composed and intended to express sadness or happiness. Other, more complex emotions like jealousy or homesickness are harder to distinguish: Music, alone, has less power to induce such feelings and to actually make us feel them. However, if you add pictures and other media to the musical expression, the musical power increases exponentially.

Auditory perception tends to dominate judgment in the temporal dimension (Avanzini,, 2008, p. 390). Music is a special case of this, since it is sound that is highly structured in time. By synchronizing sound and visual movements, very strong effects can be created.

Some of the music we hear affects us very individually: it is not universal and does not communicate the same thing to two persons. But if the music is paired with something else, for example, a film or a game, something happens. People that are said to hate classical music, and would never put on a recording of classical music, can spend hours watching films with music tracks firmly grounded in western classical music tradition, sounding like something composed in the late 19th Century by Richard Wagner or Gustav Mahler. When musical sounds meet other sensory inputs, for example, music in an animated film, the individual stimuli tend to blend together and become a new whole. The "film + music" object is perceived as being radically different from the film alone and the music alone. The music becomes more universal and has the ability to communicate relatively universal values, emotions, and moods.

Music is normally a very linear phenomenon: a song starts at A and ends at B, and the journey between the two is always the same and takes the same amount of time to travel each time. This is especially true of recorded, mediated music. In a non-linear and interactive context, this linear music concept does not necessarily apply. Most often, music has a form that creates successions of tension and relief, which in turn creates expectations on how the music will continue: the music can therefore not be altered as quickly and easily as other media. To function and be perceived as music, it has to follow at least some basic musical rules of form and continuity.

A number of techniques and systems have been developed to cope with the gap between linear music and non-linear environments. Many of these are proprietary systems developed by the commercial game developers and are not available to the general public. What most of the systems seem to agree on is a division between a vertical and horizontal dimension. The vertical dimension controls aspects of musical intensity and emotion and the horizontal dimension controls aspects of time and form. The vertical dimension is often implemented using a layered approach whereby a number of musical tracks play in parallel. Each

track plays music with a certain content representing a level of intensity or emotion and the game engine cross-fades between the tracks to create the correct blend of intensity and emotion. The horizontal dimension is often implemented using short phrases of 1, 2 or 4 bars linked together. When a transition from one musical segment to another is motivated by the state of the game, the current phrase is played to the end and the chain of linked phrases takes another route than if the game state had not changed.

3D-Positioned Audio

Since sounds are the results of physical events in three-dimensional space, it is often vital to be able to give the impression of game sound as emanating from a certain point in a 3D space (see Murphy, 2011). 3D-positioned audio is a powerful technique to bridge the gap between the virtual game reality and the physical world of the player's senses. This is especially true for sound effects but is also very useful for speech and dialog. Music and ambient sounds are most often not 3D-positioned.

SOUND FOR FANTASY AND FREEDOM

We cannot hear away from a sound like we can look away from an object, and we have no "earlids" to shut as we can our eyelids. These simple facts makes sound ideal to use if you are looking for new game concepts to contrast the traditional screen and eye-based computer games. Western societies are often said to be vision-based or eye-centric. This suggests that we rely mostly on our eyes and use our other senses and abilities more or less just as support for what we see. In language this is reflected in that we "watch" things. We "watch" TV and films despite silent movies being history since the 1930s. We even "watch" music concerts (at least this is true in Swedish). Our knowledge and awareness about vision, graphic design and so forth is also remarkably higher, more general and more common than their sounding counterparts, as are the creative tools available. In the Association for Computing Machinery's Computing Classification System (2010), sound and audio are added late compared to, for example, computer graphics. Sound and audio are also mentioned on a lower level (level three) in the classification system, whereas computer graphics is a level two item.

Balance the Senses

Our eyes play a dominant role in our everyday lives and computer game development has traditionally put most emphasis on graphics and vision. At the same time, other modalities and media types such as sound and hearing can be described as underused. This suggests that new computer game concepts could potentially be found by changing the balance between modalities and media types. What happens for example if we reduce graphics and visual stimuli and instead build the gaming experience more on sound and audition? What would the effect be if you had a computer game with only an absolute minimum of graphics and instead a rich, varied and gameplay-driving soundscape? Potentially such a game would be immersive in other ways and give different types of game experiences compared to more traditional, graphics-based games. A couple of things immediately become obvious. First of all, the game designer must let other qualities than computer graphics build and drive gameplay. Secondly the player is liberated from the need to keep her eyes on a 20-something-inch rectangle (in mobile applications only a few inches). Instead, all of a sudden, she becomes free to move over much larger areas or even volumes. Both these open up possibilities to create radically new types of computer games for radically new computer game experiences. They also represent new challenges for both game designers and computer game players (see Hug, 2011 for an expansion of such ideas).

Our auditory perception is good at interpreting sounds as tokens of events. When we hear a sound we know something has happened, matter has interacted with matter. The sounds of broken glass, of cars colliding, of footsteps, our own breathing, and combustion engines all contain information about materials, weights, speeds, surface roughness and so on. In our everyday lives we are constantly immersed in a soundscape that we receive through two streams, one in the left ear and one in the right. From day one we start training our perception in order to be able to make priorities and pick out the relevant information from these two streams. Since sound reaches us from all directions, it can be hypothesized that most of the events we hear, we do not see. In the light of the above, it becomes natural to use sounds as means to convey feedback on both player actions and other events occurring in the virtual world of a computer game. Since sound tells us in a totally natural way about things we do not see, sound can be used to expand the game world far beyond what is displayed on a screen. Sound is very well suited for delivering the feedback and creating the immersion necessary for successful game concepts, as described by the GameFlow concept above.

The use of sound to convey information about events, creatures and things that are not visible adds yet another dimension to the game experience: imagination, a word originally meaning "picture to oneself". When we hear a sound without seeing the sound source we make an interpretation of what we have heard. The interpretation is based on previous experiences of memories of and associations to sounds with similar properties. The interpretation is often subconscious and made without effort. To invite the players to use their imagination, fantasy, and associations to fill out the gaps in this way and complement what they see on the screen is one way to make the players emotionally and viscerally immersed in the game.

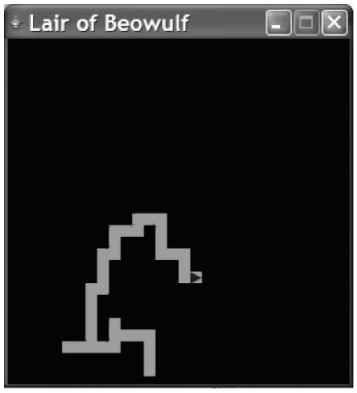
In a series of research and development projects we have conducted investigations and experiments based on questions related to the ideas outlined above. These projects have shown that by shifting the balance between graphics and other media types and between eyes and other modalities, games with new qualities can indeed be created: games that attract new user groups and games that can be used in new contexts, in new ways and for new purposes.

In this context it is also relevant to make a distinction between gameplay or game mechanics and metaphor. Gameplay can be defined as the set of rules and the mechanics that drive the game, the game's fundamental natural laws. Metaphor on the other hand defines the world in which these abstract laws work. Gameplay can, for example, define that you are able to navigate in 4 directions called north, south, east and west, that you will be presented with challenges you can either win or lose, and that you win the game by winning a defined number of these challenges. Metaphor defines the world in which the navigation takes place and the nature of the challenges. When gameplay defines an abstract challenge, metaphor can, for example, show an enemy soldier that must be eliminated or it can present the player with a falling egg that must be caught before it hits the floor. A good game must have both a well-designed gameplay and a metaphor that supports that gameplay: both are equally important. Often, the sound designer works with the metaphor side of a game. The metaphor chosen dictates the possibilities available to the sound designer. A metaphor with a large number of natural sounds that the players are likely to be able to relate to is potentially more immersive than a metaphor with few and/or unknown sounds.

Two Case Studies

In two projects, alternative ways to balance visual and audible stimuli in computer games have been explored by the Interactive Institute, Sonic Studio. In the first project, called *Beowulf*, a game for devices with limited screen size, such as cell phones,

Figure 1. The Beowulf game window



was developed (Liljedahl, Papworth, & Lindberg, 2007). In this project, the hypothesis was set up that a game with most of the graphics removed, having, instead, a rich, varied and challenging soundscape, can create a new type of immersive game experience. The hypothesis also included the idea that a game built mostly on audio stimuli will be more ambiguous and open for interpretation than a game built on visuals and that the need for the users to interpret and disambiguate the soundscape will create a rich and immersive game experience with new qualities compared to traditional computer games. The game uses both a well-known gameplay and a traditional metaphor to keep as many parameters as possible constant. Although the gameplay is very simple, the game's sound-based metaphor makes it a both challenging and rewarding game to play.

The *Beowulf* game world is graphically represented by a revealing map, a map showing only the parts of the game world you have visited so far as a red track (see Figure 1). Your position in the game world is indicated by a blue triangle pointing in your current direction. The player uses headphones to listen to the gameworld, which is described in much greater detail audially than visually. The player navigates this gameworld by listening to sound sources positioned in a 3D space. Navigating includes localizing sound sources by turning and moving to experience changes and differences just as in real life. Feedback on player actions and progress is given by footstep sounds, breathing sounds, the sound of a swinging sword, and other sounds natural in the context of the game's world metaphor. Immersion is created through the natural and effortless interaction with the sounding dimension of the gameworld.

In the second project, called *DigiWall*, the computer monitor was removed totally (Liljedahl, Lindberg, Berg, 2005). Instead, a computer game interface in the form of a climbing wall was developed (see Figure 2). The 144 climbing grips are equipped with sensors reacting to the touch of hands, feet, knees, and other body parts. The grips are also equipped with red LEDs and can be lit, turning the wall's climbing area into an irregular and very low-resolution visual display. A number of games were then developed based on a balanced mix of sounds, physical activity, and the sparse visuals of the climbing grips. The absence of traditional computer game graphics and the shift in balance between modalities and media types gives another effect: the games become open for the players to adapt to their own level of physical ability, their familiarity with the games, how they chose to team up, to create variation and so on. In this sense, the new balance between modalities and media types means new freedom for the players.

Figure 2. DigiWall climbing wall computer game interface

Both projects explored questions related to how computer game players could be offered new and unique gaming experiences in terms of freedom and fantasy. In *Beowulf* the hypothesis was that a shift in balance between eye and ear would invite the players to co-create the game experience and to bring their imagination into play in new ways, compared to traditional, graphics-based games. The studies performed on the game concept showed that, to a majority of players, this was also the case. The *DigiWall* concept is based on the players' freedom to use their whole bodies and to play the games by moving over the whole, 15m^2 game interface. The absence of a traditional computer monitor also opens up the rules of play in such a way that the users are invited to co-create and adapt the basic gameplays offered to their own needs and desires.

In this context it is also important to mention the term "user investment". Both projects eventually showed that the need to interpret and disambiguate the soundscape of the games was in fact an asset. Both games more or less forced the players to use their own imagination and experiences to flesh out the sounding skeletons supplied by the game's metaphors. In the *Beowulf* case, the user investment was expressed as high-ranking in game satisfaction as well as in vivid descriptions of the gameworld's environments, materials, temperature, atmosphere, inhabitants and so forth none of which had any visible cues. In the *DigiWall* case, positive user investment ranked highly both in player satisfaction and the subsequent publicity and commercial success of the project.

In these projects, audio is used in a number of ways to create a sense of presence and to link, as closely as possible, the virtual reality of the game to the physical reality of the player. Sound was also used to communicate instructions, cues, clues, feedback, and results from the game to the player. The aim was to create new balances between sound and graphics compared to traditional computer game applications and to explore if and how sound could be used to drive gameplay and to create fun, challenging, rewarding and immersive gaming experiences. The aim was also to use sound to blur the borders between the virtual reality of the game and the physical reality of the player. In both cases, game metaphors were chosen to match the gameplays and to present as many possibilities and large design spaces as possible for the sound designers.

Here follows a brief description of how sound was implemented in the two projects.

Ambience and Background to Bridge the Reality Gap

Physical environments are (almost) never silent. Air, water, objects, creatures and machines around us all more or less make sounds. The absence of sound is unnatural and scary; it is an auditory counterpart to pitch black. Sounds are the signs of presence, life and function. By adding just a very soft sound of moving air, an otherwise dead and detached game environment can come alive. If the sound is well designed, it is possible to create an experience where the game-generated sounds blend with the sounds from the gamer's physical environment, creating an inseparable whole. The gap between the realities closes.

Ambient sounds can be strong carriers of emotion and mood. They share this ability with music and the fact is that the border between the two is more and more often blurred by film and game sound designers (Dane Davis, cited in Sonnenschein, 2001, p. 44). Carefully "composing" an ambient or background sound can serve several purposes at the same time. It can create a sense of physical presence, it can set the basic mood and it can communicate emotion and arousal.

In the *Beowulf* game, the ambient sounds were the sound of air softly flowing through the game-world's system of caves and tunnels. The sounds had a slight amount of reverb added to create a sense of volume in the caves and the reverb was removed for tunnels. The ambient sounds were also deliberately freed as much as possible from musical components such as pitch and rhythm: We wanted to give the players as much freedom as possible to use their own imagination, not influencing them in any direction defined by us more than necessary.

Most of the *DigiWall* games use music tracks as ambient and background sounds. In this case the purpose is the opposite. Music is used to set the basic mood of the games and to encourage physical activity in the players. The music is designed to communicate subconsciously with the players and, for example, "whisper" that speed is increasing or that time is running out and you must hurry.

Sound Effects and Music for Cues and Clues

Often game designers want to encourage the players to go in certain directions or to take certain actions. By carefully planting sound effects and/or music, the player can be guided, inspired or even intentionally misled. *Beowulf* uses a large number of natural sounds to warn the player of potential dangers such as predators, bottomless holes or boiling lava. The *DigiWall* games use music and sound effects with musical properties to guide attention in certain directions on the wall. One example is the game *Catch The Grip*, in which the direction from the last grip caught to the next to catch is represented by a series of notes. The length of the series tells the physical distance on the wall. The panning of the notes in the loudspeaker system signals the direction left/right. In the game *Scrambled Eggs*, sound effects with a falling pitch denote the movement of "eggs" falling from the top of the wall towards the floor.

Speech, Music and Sound Effects for Information and Feedback

Many sounds are emotional and meant to create and communicate mood and presence. Other sounds are meant to convey cognitive information about rules, scores, results and so forth. Speech is, of course, very versatile and useful in this case. It is very effective to have a voice read the initial instructions for a game, especially if it is a game with relatively simple gameplay and few rules. The same is true for scores and results. Who won, the left or right team? How many points did you score? To have a voice read these results creates a strong feeling of presence and makes the game come alive. One drawback with speech is, of course, language. For example, Swedish voice-

overs in a game do not make very much sense in the UK. As with text, it is necessary to have localized versions and this quickly starts adding cost in terms of computer memory, coding, development time, and other resources. But then again, sometimes it is worth it. In the *DigiWall* games serving as an example here, speech is used as introduction to all games. A majority of the games also present scores and results using speech. The *DigiWall* game interface is equipped with two buttons, so the players can select one of two available languages.

A danger with speech is the risk of wearing out often-repeated phrases. It is therefore useful to give the players the option to skip, for example, instructions when they are no longer needed.

Music and sound effects can also serve as carriers of information, albeit not as clear and unambiguous as speech. This is not an innate disability though, but rather an effect of the way we use music and sound effects. Rhythm, for example, can be used to convey semantics just as well as any speech: what is required is simply to learn the system (Morse code, for example). One of the advantages with sound effects and music is that they are not limited by language, but are more universal. This can of course be used in many ways. In the *Beowulf* game, each new round starts with a short, horn melody, as if it were announcing the approach of the king's ambassador. The players learn very quickly what this signal means and, since it is very short, the risk of becoming bored with it is minimal. *Beowulf* also uses pure music to signal success and failure. Success is signaled by a short triumphant brass fanfare and failure is signaled by a short funeral march.

By carefully selecting the metaphor aspect of a game's design, tremendous opportunities to create sound effects for feedback and information can be opened up. By placing the game in an environment (metaphor) that the players are likely to have some kind of relation to, the designer can choose sounds for feedback and information that are natural in that environment. Using natural sounds that the players can immediately relate to can greatly enhance the gameplay aspect of the same game as well as create the sought-after sense of presence and immersion. The *DigiWall*'s game *Scrambled Eggs* uses the sound of broken eggs to signal points lost and the sound of an egg rescued in the palm of your hand to signal points gained. In *Beowulf*, if the player enters a forbidden game tile, the sound of a scream receding down a hole together with the sound of falling rocks signals life lost. When this is followed by the funeral march, failure and the end of the game are obvious to anyone, without the need for speech or text.

FUTURE RESEARCH DIRECTIONS

It is often said that sound is still underused and that audio is a media type with potential yet to be unleashed. In order to free this unused potential, research and development efforts must be carried out on several parallel fronts. We need to develop more in-depth knowledge about auditory perception and how heard experiences affect users of computer games and other interactive systems. This also implies richer taxonomies and more developed languages for writing about, talking about and reflecting over this new knowledge and making it useful in wider contexts. Furthermore, a number of current ideas and traditions in the field must be challenged and a set of updated ideas must be developed. Ambiguity and wider interpretation spaces treated as design assets rather than problems in the design of interactive systems is one example. Another example is when simple efficiency metrics for player enjoyment are replaced with more complex systems for the design and evaluation of computer game experiences, such as the GameFlow concept. Finally, new technology that can carry and realize the new knowledge and ideas must be developed. This includes technologies for procedural audio (see Farnell, 2011; Mullan, 2011 for further descriptions of this technology)) and systems for dynamic

simulation of room acoustics and acoustic occlusion and obstruction, just to name a few.

CONCLUSION

Sound is a complex stimulus and it is only in recent years that science has started to understand auditory perception in any depth. Much of the knowledge and practice in sound design for computer games and other interactive applications is based on experience and anecdotal evidence. But the awareness of sound's potential and scientifically-based knowledge in sound design is slowly increasing. This is not only true in the computer game industry, but in industry and society in general. The implications of the fact that our ears and our eyes complement each other are slowly beginning to have an effect. Graphics alone gives one type of experience: sound alone gives another type of experience, and graphics plus sounds gives new and unique experiences. By working with the balance of ears, eyes and other senses and human abilities, new opportunities emerge for the computer game designer. The *Wii*, *Dance Dance Revolution* and *DigiWall* are just a couple of examples of this.

Sounds in the physical reality of our bodies are the results of physical events in that same reality. Our hearing is designed and "hardwired" to constantly scan and analyze the soundscape surrounding us and react rationally to the sounds heard. Most of the time this is done subconsciously and our hearing can therefore be described as, to a large degree, intuitive, emotional, or pre-cognitive. The soundscape reaching our ears demands interpretation and disambiguation in other ways than the visual stimuli reaching our eyes. This need to interpret and disambiguate can be turned into a great asset in computer game design. A game with a well-designed, rich, and varied soundscape will play on the user's intuition and emotions: the game will be immersive and give fun and rewarding gaming experiences.

How we interpret a sound depends on, and draws from, our previous personal experiences. Well-known sounds will spawn a myriad of pictures in our inner, mental movie theaters. Unknown sounds can create both confusion and excitement. Working in parallel with the gameplay and the metaphor aspects of computer game design, and making sure that the two match and support each other, is a powerful way to find and design the sounds that build the total soundscape of the game. By working in parallel with and carefully balancing the graphics and the sounds of a computer game the users' bodies and fantasies can be set free, creating unique, immersive, and rewarding gaming experiences.

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KEY TERMS AND DEFINITIONS

Auditory Perception: The process of attaining awareness or understanding of auditory information or stimulus.

Avatar: A controllable representation of a person or creature in a virtual reality environment.

Feedback: Output from a computer game to inform the user of various changes in game state.

Flow: The mental state of operation in which a person is fully immersed in what he or she is doing by a feeling of energized focus, full involvement, and success in the process of the activity.

Gameplay: The rules and mechanics defining the functionality of a computer game.

Game Metaphor: The embodiment of the virtual environment comprising the game world.

Immersion: Deep mental involvement.

Pervasive Game: A computer game tightly interwoven with our everyday lives through the objects, devices and people that surround us and the places we inhabit.

Suspension of Disbelief: A silent agreement between an audience and an entertainment producer in which the audience agrees to provisionally suspend their judgment in exchange for the promise of entertainment.